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What Makes an Allocation Fair? Some Experimental Evidence[1]

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We explore three two-person public goods games with similar equilibrium predictions, but with different rules of the game, different payoff possibilities, and, as we show, different choices by subjects. Comparisons among games allow inferences of what may or may not determine when the equilibrium prediction is a good approximation of actual behavior. We find that the equilibrium prediction can fail even when incentives off the equilibrium enforce it. Our result suggests that the selfish prediction is prone to deviations when the equilibrium results in unequal distributions of payoffs, and there are alternative outcomes that increase both equality and the payoff of the disadvantaged party. Furthermore, fairness is a function of more than just the final allocations to subjects; it depends on the actions not chosen as well as those that are. *Journal of Economic Literature* Classification Numbers: C92, H41.

1. INTRODUCTION

Experimental evidence has demonstrated that the selfish equilibrium prediction frequently is a poor approximation of actual behavior. Games in

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which the equilibrium results in an unequal distribution of payoffs appear to be particularly vulnerable to deviations. This has convinced many researchers that concerns for fairness matter for experimental subjects.[2] Many now see fair or unselfish behavior as a trait in people's preferences, much like the taste for another commodity or activity. It is a complicated task, however, to determine and model just what goes into a person's calculation of what makes an allocation fair. Particularly tricky is the fact that selfish equilibrium predictions are precise in some games but are misleading in others, even in very similar games. First and foremost, therefore, a model of fairness must be able to predict when fairness will dominate the selfish equilibrium predictions and when it will not.

A complication in determining when the selfish equilibrium prediction is a good approximation is that fairness seems to be sensitive to subtle, often non-strategic, changes in the environment. A model must be able to determine how these seemingly non-strategic factors nonetheless come to affect strategies and outcomes. This paper addresses this challenge by comparing three slightly different versions of a two-player public goods game. The games all have similar equilibrium predictions but differ in the behaviors chosen by subjects. In comparing the three games we are able to identify some of the important factors that any theory of fairness must address.

It has been argued elsewhere that the selfish equilibrium prediction is more likely to be observed if the incentives off the equilibrium path "enforce" equilibrium play. We find that this distinction is not helpful in characterizing our results. Rather, our results indicate that the selfish prediction is prone to deviations when the equilibrium results in an unequal distribution of payoffs, and there are alternative outcomes that increase both equality and the payoff of the disadvantaged party. An important finding is that the alternatives that were *not* chosen affect the evaluation of fairness of those alternatives that actually are chosen. Hence, we argue that a crucial input to the fairness of any given allocation is the set of other allocations that *could have been* chosen—it is not simply the intentions of subjects to play fairly that matters, but also the opportunities to play fairly.

The next section provides a brief summary of the key findings on altruism and fairness. In Section 3 we discuss the experimental design and the

[2] See, Forsythe *et al.* (1994) for an example of fairness in bargaining games, or see the extensive review on bargaining by Roth (1995) or the discussion by Guth (1995). For examples of related effects in models of gift exchange, see Fehr *et al.* (1993), in centipede games see McKelvey and Palfrey (1992), in public goods games see Andreoni (1995) or Ledyard (1995), and for the Prisoner's Dilemma see Andreoni and Miller (1993). For evidence on fairness in market transactions see Kahneman *et al.* (1986), and in coordination games see Van Huyck *et al.* (1992). Also related are games on "trust," such as those discussed by Van Huyck *et al.* (1995) and Berg *et al.* (1995).

equilibrium predictions, and in Section 4 we present the results. In Section 5 we summarize the primary findings of the experiment and determine whether these can help us determine what encourages non-equilibrium behavior. Section 6 is a conclusion.

2. BACKGROUND AND MOTIVATION

Many experiments have indicated that subjects have a preference for altruism. Perhaps the most direct evidence of "rational altruism" is offered by Andreoni and Miller (2002). They present subjects with a series of budgets for payoffs between themselves and another subject, and go on to check subjects' choices for consistency with the axioms of revealed preference. They find that behavior is consistent with a significant preference for altruism, and with a well-behaved preference ordering over own- and other-payoff. Moreover, preferences appear to be convex, but not always monotonic.

When turning to sequential games, it becomes clear that altruism alone cannot explain everything. This is easily illustrated in ultimatum games. Here the proposer offers a share X of a pie of, say, \$10 to a responder. If the responder accepts the offer he gets X and the proposer gets $\$10 - X$, but if the responder rejects the offer both sides get nothing. This game has been conducted with pies of \$1, \$5, \$10, and on up to \$100, and each time the results look similar—the modal split is 50% and offers of less than 30% are likely to be rejected.[3] This illustrates a willingness to pay to refute unfair treatment or to punish selfishness in others.

This willingness to pay to refute unfairness is illustrated quite clearly by Ochs and Roth (1989). They conducted two- and three-stage alternating offer bargaining games in which the pie shrinks after each rejection. Remarkably, they find many examples of "disadvantageous counterproposals," that is, player two rejects an offer and then makes a counterproposal that yields him less than he would have gained had he accepted the original offer.[4] Moreover, many rejected offers were Pareto superior (in a monetary sense) to the counterproposals, which would appear inconsistent with purely altruistic motives. Instead, as Ochs and Roth note, the fact that outcomes with Pareto inferior payoffs were revealed to be preferred by some responders suggests that subjects care how their payoff compares with that of others.

[3] Hoffman *et al.* (1996) show that behavior is similar with \$10 and \$100 pies. Slonim and Roth (1998) replicate this finding but show that differences do emerge with repetition, as those in high-stakes games are less likely to reject unequal offers.

[4] Ochs and Roth also found disadvantageous counterproposals in the data of Guth *et al.*(1982), Binmore *et al.* (1985) and Neelin *et al.* (1988). See Ochs and Roth's Table 6.

Prasnikar and Roth (1992) follow up on this insight by comparing the ultimatum game with a two-person best-shot game (Harrison and Hirshleifer, 1989). Best-shot is a sequential game in which a public good is supplied at the maximum of the two players' contributions. These two games are similar in that both have subgame perfect predictions of unequal payoffs. However, the equilibrium prediction is rarely observed in ultimatum games, while it is commonly the outcome in best-shot games. Prasnikar and Roth argue that this can be explained by the incentives off the equilibrium. In the ultimatum game, the second mover's incentives to accept an offer increase the further it is from the equilibrium, whereas in the best-shot game the incentives for the second mover to choose the best reply increase the closer the first move is to equilibrium. Hence, deviations from the equilibrium enforce free riding in the best-shot game but not in the ultimatum game. This important observation—one that is missing in theoretical models—will be reexamined in our study.[5]

Next we describe an experiment designed to organize and build upon these various findings. The study is designed to pinpoint what makes an allocation fair, and therefore what may cause the equilibrium prediction to fail.

3. EXPERIMENTAL DESIGN

We consider three slightly different versions of a two-person public goods game, where all three versions have equilibrium predictions that entail very unequal payoffs. The three games allow us to determine what effect the off-the-equilibrium-path payoffs have on deviations. Furthermore, we can look at two issues regarding the ability and willingness to play the selfish best response when the equilibrium payoffs are unequal. First, we compare two games with identical payoff structures, but which differ in the players' abilities to commit to a free-riding strategy. Next we compare two games in which players have equal ability to commit to a free-riding strategy, but which differ in the payoffs off the equilibrium path.

3.1. *Model*

To motivate the game, consider the simple theoretical model in which two people provide a public good. Let x_i be consumption of a private good

[5] This interaction of fairness and strategic features is underscored by Kagel *et al.* (1996). They study ultimatum bargaining with asymmetric information about the values of the pie. They find that both proposers and responders appear to make good use of any informational advantage to move the outcome toward a more self-serving notion of fairness.

by i and let g_i be i's contribution to the public good. Each individual faces a budget constraint $x_i + g_i = m_i$. Define $G = g_1 + g_2$ as the total supply of the public good. Assume individuals each have utility functions $U_i = x_i + \alpha_i \ln G$, where $\alpha_1 > \alpha_2$. Then it is easy to verify that the best reply function for each player will be $g_i = \max(0, \alpha_i - g_j)$, $j \neq i$, that is, each player wants to bring the total contributions up to the level $G = \alpha_i$. If G is provided through simultaneous contributions, then, since $\alpha_1 > \alpha_2$ the Nash equilibrium will be $g_1 = \alpha_1$, and $g_2 = 0$. Pareto efficiency, on the other hand, requires $g_1 + g_2 = \alpha_1 + \alpha_2$.

Next assume the game is played sequentially: player one moves first and player two moves second, and each player moves only once. Now if α_1 and α_2 are not too different, the subgame perfect equilibrium is for player one to commit to choosing $g_1 = 0$, leaving player two to choose $g_2 = \alpha_2$. Being in a position to commit to free riding, player one is clearly better off, and player two is worse off. In addition, since $\alpha_1 > \alpha_2$ the total supply of the public good is predicted to be lower than in the simultaneous case (Varian, 1994), but the set of Pareto efficient allocations remains unchanged.

Finally, consider a variant of this sequential game in which $G = \max\{g_1, g_2\}$. This is now a best-shot game where the supply of the public good is determined by the maximum of the two contributions. Again, let player one move first. Now the best reply function for player two is $g_2 = \alpha_2$ if $g_1 \leq \alpha_1/\exp(1)$, and $g_2 = 0$ otherwise. As in the sequential game, the subgame perfect equilibrium is $g_1 = 0$ and $g_2 = \alpha_2$. However, Pareto efficiency requires one of the players to contribute zero. Hence any allocation such that $g_i = 0$ and $\alpha_j \leq g_j \leq \alpha_1 + \alpha_2$, $j \neq i$, is Pareto efficient.

Notice that if subjects are assumed to be money-maximizers then all three versions of this game have very similar equilibrium predictions, that is, one player provides all of the public good and earns a low payoff, while the other player completely free-rides and earns a high payoff. In addition, selfishness implies that the sequential and simultaneous versions of this game have identical payoffs both on and off the equilibrium path, but differ only in the ability of players to commit to free riding. The sequential and best-shot games have identical equilibrium payoffs, and in both games the first contributor can commit to free riding, but the off-the-equilibrium-path payoffs differ. Comparing simultaneous with sequential play of the game will allow us to see how the ability to commit to free riding affects the outcome, and comparing the sequential to the best-shot games will allow us to see how off-the-equilibrium-path payoffs affect the willingness of players to accept subgame perfect equilibria with unequal payoffs.

Note that our design allows a special test of the central conjecture of Prasnikar and Roth (1992). For all three games the predicted contributor's marginal incentive to contribute decreases with the predicted free rider's contribution. Prasnikar and Roth therefore would argue that deviations are

Investment Returns to RED and BLUE Investors
Based on Total Investment by Both Investors.
(Returns are Listed in Cents)

Total Investment Units Purchased by Both Investors	Total Return to RED from total investment	Additional Return to RED from just the last unit	Total Return to BLUE from total investment	Additional Return to BLUE from just the last unit
0	0		0	
1	15	15	16	16
2	30	15	32	16
3	45	15	48	16
4	60	15	64	16
5	75	15	80	16
6	90	15	93	13
7	103	13	104	11
8	114	11	115	11
9	125	11	124	9
10	134	9	132	8
11	142	8	139	7
12	149	7	146	7
13	156	7	152	6
14	162	6	158	6
15	168	6	163	5
16	174	6	168	5
17	180	6	173	5
18	185	5	177	4
19	190	5	181	4
20	194	4	185	4
over 20	194	0	185	0

Reminder: Investment Units cost 10 each.

FIG. 1. Payoff table for simultaneous and sequential Games.

not encouraged, and that equilibrium play is enforced in all three games. Hence, this is not likely to be a predictor of any differences observed in our experiment.

3.2. *Experimental Parameters*

The experiment will have three conditions: the simultaneous summation game, the sequential summation game, and the sequential best-shot game. We will refer to these as *simultaneous, sequential*, and *best-shot*.

The payoff table used in the experiments reported here is shown in Fig. 1. It contains all of the incentives described in the theoretical model above. The game is played with two players. In the experiment, player one is named Red and player two is named Blue. Players must decide how many "Investment Units" to purchase. Investment units cost \$0.10 each. In Fig. 1 the payoff from the public good to each subject depends on the total number of investment units purchased. In the simultaneous public goods game, both players make their choice without knowing what the other will choose, while in the sequential public goods and best-shot game, Red moves first.

As can be verified, the Red subjects would, if acting alone, bring the total up to 9 investment units, while the Blue subjects would bring the total up to 8. That is, the best replies are $g_1 = \max(0, 9 - g_2)$ and $g_2 = \max(0, 8 - g_1)$. The Nash equilibrium in the simultaneous game is thus $g_1 = 9$ and $g_2 = 0$; Red earns \$0.35, and Blue earns \$1.25. In the sequential game the subgame perfect equilibrium is nearly the opposite: $g_1 = 0$ and $g_2 = 8$, with a payoff to Red of \$1.14 and a payoff to Blue of \$0.35. In both cases it is Pareto efficient for $g_1 + g_2 = 17$.

Converting this game to the best-shot is trivial. Simply replace the heading in the first column in Fig. 1 with the words "The greater of the investment units purchased by Red or Blue." Replace the heading above the third column with "Additional return to Red from raising the greatest investment by 1" and make a similar adjustment to the final column heading. Exactly the same payoff table is used, but the definition of the public good changes from the total supply of investment units to simply the greater of those invested by the Red and Blue players. The players' best replies differ from that found above, with $g_1 = 9$ if $g_2 \leq 2$, and $g_1 = 0$ otherwise, and $g_2 = 8$ if $g_1 \leq 2$, and $g_2 = 0$ otherwise. As above, the subgame perfect equilibrium is $(g_1, g_2) = (0, 8)$ with payoffs again of \$1.14 and \$0.35. Pareto efficiency requires either $g_1 = 0$, $8 \leq g_2 \leq 17$ or $g_2 = 0$, $9 \leq g_1 \leq 17$. Thus, the predictions are that in each game one player provides all of the public good and earns a relatively small amount of money.

A session of our experiment went as follows. We recruited 14 subjects per session from economics courses at the University of Wisconsin. Subjects were randomly assigned to computer terminals, separated by blinders, in a computer classroom. Subjects were given written instructions, which the experimenter read over with the participants. The experimenter then gave a quiz, asking subjects to calculate the payoffs in a specific example of the game, which was collected and reviewed verbally. Half of the subjects were then randomly assigned to be Red players and half to be Blue, and they were informed that they would play the same role throughout the experiment.[6] The subjects then were walked through an example using the computers, and the experiment began. They played 14 iterations of the game. In each iteration they were randomly and anonymously paired with another subject, with the stipulation that no one played another subject more than twice. Subjects' identities were never revealed to one another.

[6] Coats and Gronberg (1996) also consider a sequentially provided public goods game. Their experiments are quite different, however, since they employ a discrete public good, and their subjects change roles each round.

After the 14 rounds, subjects participated in a “bonus round” which was designed to test their understanding of the game. Finally, the subjects’ earnings for all 14 rounds were tallied and added to a \$3 show-up payment and earnings in the bonus round. Subjects were paid anonymously and in cash. We ran three sessions of each of the three games, for a total of 126 subjects. The experiment typically lasted less than an hour, and subjects made an average of \$12.85 (standard deviation of \$2.10, maximum of \$19.25, and minimum of \$5.00). A copy of the instructions for the sequential game is given in the Appendix.

4. RESULTS

We begin by asking how well the data conform with the equilibrium predictions. The average contributions for all three games are illustrated in Fig. 2. Over the 14 rounds, the simultaneous game produces an average G of 8.55, sequential produces 7.15, and best-shot 6.86. Over the last five rounds, the average level of G is similar across all three games: 7.16 for simultaneous, 6.55 for sequential, and 7.33 for best-shot.

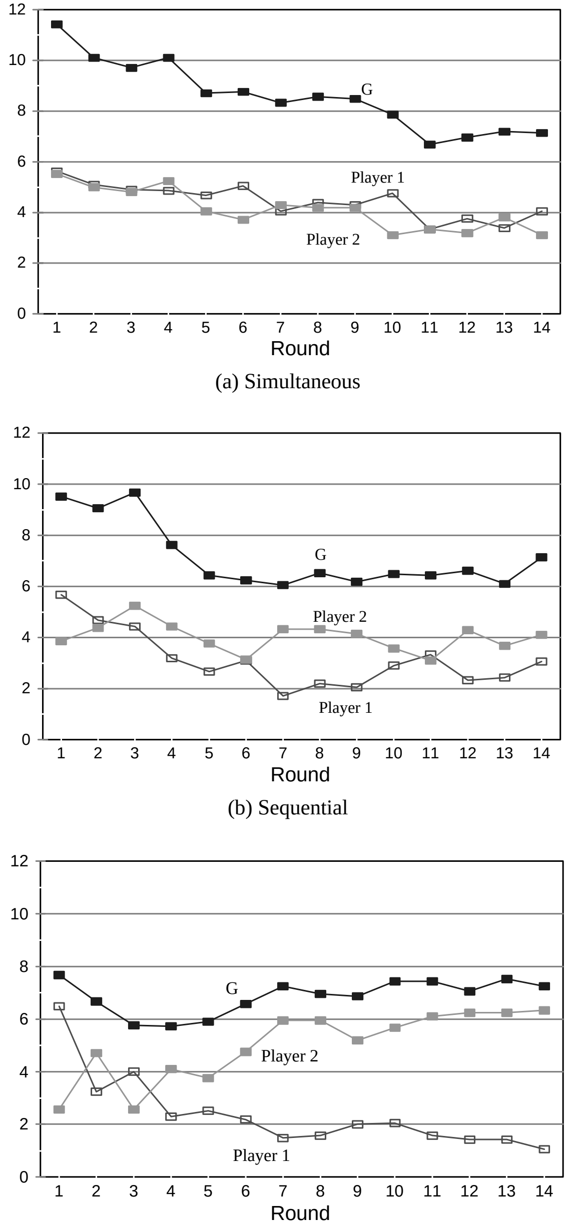
When we explore the individual contributions, however, the differences in the games become apparent. Figure 2a shows that the average choices for the two players are almost identical for every round in the simultaneous game, despite the prediction that player one would choose 9 and player two would choose 0. Although outcomes in 10 of the 14 rounds show more giving by player one on average, the difference is not statistically significant.[7]

Figure 2b gives the same information for the sequential game. In this game, the subgame perfect equilibrium is that player one chooses 0 and player two chooses 8. Here we see more separation between the players, with more given to the public good on average by player two. While the difference is clearly larger than in the simultaneous game, again the difference is not statistically significant, and play of the subgame perfect equilibrium is still fairly uncommon.[8]

Finally, Fig. 2c shows the results for the best-shot game. By the middle of the game, most interactions between subjects actually occur at the subgame perfect equilibrium. Over the last five rounds, 61% of all best-shot games are at the predicted outcome. This compares with 17% of the

[7] Looking at individual subjects, a rank-sum test reveals no significant difference between the choices of the two types of players. A rank-sum U-test comparing average choices by subjects over all 14 rounds yields a z score of $z = -0.553$. Looking at only the last five or last three rounds yields $z = -1.044$ and $z = -0.623$, respectively. A description of this test can be found in Freund (1971, pp. 347–349).

[8] The rank-sum U-test yields $z = 1.484$ over all rounds, $z = 1.019$ for the last five rounds, and $z = 1.635$ for the last three rounds.



(a) Simultaneous

(b) Sequential

(c) Best-shot

FIG. 2. Average contributions by round.

sequential plays and only 1% of the simultaneous plays. Hence, we have our first main result. The selfish equilibrium prediction is a poor approximation of actual behavior in both the simultaneous and sequential games, but is a very good approximation in the best-shot game, despite the similar game-theoretic predictions of the three games, and despite the equilibrium-enforcing incentives. Next we look more closely at the differences across the games.

4.1. *Comparing the Simultaneous and Sequential Games*

Table I shows the average choices of all players in the simultaneous public goods game for all sessions. Here we see no sign of Nash equilibrium play, but rather choices are very equitable—players give similar amounts to the public good, whether measured by the average or the median. Likewise, Table II shows the choices in the sequential public goods game. Again, we see very little evidence of the selfish equilibrium prediction, but rather choices that are fairly equitable, with the second players giving somewhat more on average than first players.[9]

Looking at each player one's role and using a non-parametric rank-sum test, we see that over all rounds player one in the simultaneous game gives significantly more than his counterpart in sequential games ($z = 2.113$). However, by the end of the experiment the difference has largely disappeared (for instance, $z = 1.270$ for the last three rounds). Comparing the second players in the simultaneous and sequential games, the overall difference is not at all significant ($z = -0.075$), and the difference stays insignificant throughout the experiment ($z = 0.780$ for the final three rounds). While the pressures of equilibrium should cause players of the same role to be significantly different across games, we see that the pressures for fairness are exerting roughly equal force in the two games—by the end of the game, players of a given role are behaving, on average, similarly in the two games.

4.2. *Comparing Sequential to Best-Shot Games*

Table III presents results from the best-shot game. Here we see that the first players in the best-shot game are much more likely to choose the subgame perfect contribution of zero. Over the last five rounds, 10 of 21 choose $g_1 = 0$ all five rounds, and 16 of 21 choose less than 1 on average. Over all rounds, the average player one chooses 2.36, with a median choice of 1. By the end of the game, however, most choices are zero, as predicted.

[9] Sequential and simultaneous play of a game of "claiming" shares in a finite resource was considered by Budescu *et al.* (1992). They also find that simultaneous play generates more fair play, and the first-movers fail to exploit their full bargaining power.

TABLE I
Choices in the Simultaneous Public Goods Game, $G = g_1 + g_2$

Subject Number	Average g_1 All rounds	Average g_1 Last 5 rounds	Round adopted $g_1 = 9$	Subject Number	Average g_2 All rounds	Average g_2 Last 5 rounds	Round adopted $g_2 = 0$
Session 1							
1	2.36	1.6	—	2	4.29	2.8	14
3	3.58	2.2	—	4	2.79	2.6	—
5	3.36	2.2	—	6	3.07	0.8	11
7	3.64	2.8	—	8	5.50	1.6	11
9	5.21	4.0	—	10	5.93	4.4	—
11	5.57	4.2	—	12	4.36	2.4	—
13	2.71	2.2	—	14	4.71	4.0	—
Session 2							
1	1.86	0.0	—	2	3.39	0.8	14
3	5.64	3.4	—	4	2.50	4.0	—
5	4.14	4.6	—	6	4.64	4.2	—
7	2.29	1.6	—	8	3.64	2.0	14
9	6.29	4.2	—	10	8.00	8.0	—
11	4.71	4.4	—	12	2.57	2.0	—
13	4.57	3.4	—	14	4.86	3.6	—
Session 3							
1	4.36	4.0	—	2	0.72	0.6	—
3	3.5	6.0	—	4	0.00	0.0	1
5	4.43	3.8	—	6	7.36	7.8	—
7	7.71	7.2	—	8	1.93	1.6	—
9	3.36	3.4	—	10	5.00	5.4	—
11	7.64	7.6	—	12	3.14	2.8	—
13	6.36	8.2	13	14	8.00	8.0	—
Mean	4.44	3.9			4.11	3.3	
Median	4	4	—		4	3	—

In fact, more than half of all subjects choose $g_1 = 0$ for all rounds after 11, and 16 of 21 choose zero in the final round—twice the number in the sequential public goods game.

Five best-shot players are worth special note. Player 3 in session 1 and player 3 in session 3 both chose 9 throughout most of the experiment. A post-experiment questionnaire reveals that these subjects mistakenly inferred (the first after being punished early on) that as the first player they were in the disadvantaged position.[10] Subject 5 in session 2 settles on

[10] Since they choose 9 and get 0 as a reply for the rest of the game, they learn nothing to disabuse them of this belief. This is suggestive of a notion put forth by Fudenberg and Levine (1997) on how subjects learn only the part of the game tree they experience. Here a bit more experimentation with free riding may have taught these two subjects to behave differently.

TABLE II
Choices in Sequential Public Goods Game, $G = g_1 + g_2$

Subject number	Average g_1 All rounds	Average g_1 Last 5 rounds	Round adopted $g_1 = 0$	Subject number	Average g_2 All rounds	Average g_2 Last 5 rounds	Average G All rounds	Average G Last 5 rounds
Session 1								
1	2.14	2.8	—	2	5.93	5.0	8.86	8.0
3	6.00	5.6	—	4	3.79	1.4	6.21	3.2
5	3.36	2.6	—	6	4.21	2.0	7.21	6.0
7	4.71	4.6	—	8	5.00	4.2	8.14	8.0
9	3.00	3.0	—	10	2.21	3.0	5.79	6.0
11	0.50	0.6	13	12	5.14	6.2	8.21	8.0
13	1.36	0.2	11	14	3.93	4.4	6.86	6.4
Session 2								
1	0.71	0.0	4	2	1.57	1.6	5.50	5.4
3	1.07	0.0	4	4	4.07	2.6	5.71	3.4
5	2.57	0.4	12	6	4.07	5.6	5.21	6.4
7	4.14	4.2	—	8	6.00	7.2	8.07	8.0
9	3.50	3.4	14	10	2.43	1.8	6.36	7.6
11	5.21	6.4	—	12	3.21	2.0	6.43	4.8
13	1.36	1.8	—	14	3.36	1.8	6.00	3.2
Session 3								
1	0.79	0.0	3	2	4.07	4.2	8.64	8.0
3	3.79	3.6	—	4	4.86	4.0	9.14	8.2
5	2.14	2.4	—	6	2.57	1.8	5.71	5.2
7	4.21	3.2	—	8	7.57	9.6	10.21	10.4
9	5.14	4.0	14	10	1.64	2.0	4.43	4.8
11	5.64	4.8	—	12	4.86	3.0	9.07	8.2
13	4.21	5.4	—	14	4.0	5.2	8.29	8.4
Mean	3.12	2.8			4.02	3.7	7.15	6.5
Median	3	3	—		4	3	8	8

giving 1, but then gives 2 in the final round, and subject 9 of session 1 gives 1 each round, beginning in round 6. In a post-experiment questionnaire, these two express a desire to appease the second movers by sacrificing a token amount. Finally, subject 7 in session 2 alternates between giving 0 and 9. The post-experiment questionnaire revealed that this person is trying to share the burden with the second movers but clearly understands the subgame perfect equilibrium. Hence, although concerns for fairness are present the selfish prediction is an attractive tool for organizing the data in the best-shot game.

Allowing these subjects to observe actual play of one other pair of subjects might have altered their behavior (e.g., Duffy and Feltovich, 1999).

TABLE III
Choices in Best-Shot Game, $G = \max(g_1, g_2\}$

Subject number	Average g_1 All rounds	Average g_1 Last 5 rounds	Round adopted $g_1 = 0$	Subject number	Average g_2 All rounds	Average g_2 Last 5 rounds	Average G All rounds	Average G Last 5 rounds
Session 1								
1	2.79	0.8	—	2	6.36	6.4	8.21	8.2
3	7.50	9.0	—	4	5.71	6.4	7.93	8.2
5	0.79	0.0	7	6	4.64	6.4	7.86	8.2
7	0.86	0.2	11	8	1.57	1.4	3.36	3.4
9	1.86	1.0	—	10	5.71	6.4	8.00	8.2
11	1.57	0.0	4	12	5.86	8.2	7.43	8.2
13	1.50	0.0	4	14	2.29	2.2	2.36	2.2
Session 2								
1	1.86	0.2	12	2	4.71	8.0	6.86	8.0
3	1.14	0.0	7	4	5.71	8.0	7.93	8.0
5	2.57	1.2	—	6	1.86	0.0	3.14	0.4
7	4.29	3.4	14	8	4.29	5.8	5.07	7.4
9	0.71	0.0	4	10	6.86	8.0	8.14	8.0
11	1.36	0.8	14	12	6.36	6.4	7.36	8.2
13	0.93	0.0	7	14	6.86	8.0	7.93	8.0
Session 3								
1	2.29	0.0	6	2	5.14	4.8	8.64	10.4
3	9.00	9.0	—	4	4.86	6.4	6.57	8.2
5	0.64	0.0	2	6	4.93	8.8	7.79	8.2
7	0.71	0.0	4	8	5.43	6.4	7.29	10.6
9	3.29	4.8	13	10	5.71	6.4	7.71	8.2
11	1.00	0.0	7	12	5.79	6.4	7.86	7.4
13	3.00	0.4	12	14	4.14	6.4	6.57	6.4
Mean	2.36	1.5			4.99	6.1	6.86	7.3
Median	1	0	11		8	8	8	8

How does the best-shot game compare with the sequential game? Those in the player one role give significantly more in the sequential game than in the best-shot game. Interestingly, however, this difference only emerges later in the experiment. In the first five rounds of the game, the sequential and best-shot first players behave similarly, with average contributions of 4.12 and 3.70, respectively ($z = 0.955$). By the end of the experiment the difference is highly significant, with contributions for the last five rounds of 2.81 for sequential and 1.47 for best-shot ($z = 2.465$).[11] The second players behave differently throughout. Over the first five rounds the best-shot second players give (marginally) significantly less than sequential, 3.54 versus 4.33 ($z = -1.90$), but over the last five rounds give significantly more,

[11] Over all 14 rounds, the difference is marginal, with $z = 1.736$.

TABLE IV
Punishments by Second Movers to Low Contributions to First Movers

	Prob. $g_1 = 0$	Prob. $g_2 = 0$ given $g_1 = 0$	Prob. $g_1 \in [0, 2]$	Prob. $g_2 \in [0, 2]$ given $g_1 \in [0, 2]$
Sequential public goods				
All rounds	26.5	30.8	45.2	37.6
Rounds 1–7	22.5	30.3	40.1	33.9
Rounds 8–14	30.6	31.1	50.3	40.5
Best-shot game				
All Rounds	47.6	11.4	72.4	18.8
Rounds 1–7	30.0	13.6	59.9	23.9
Rounds 8–14	65.3	10.4	85.0	15.2

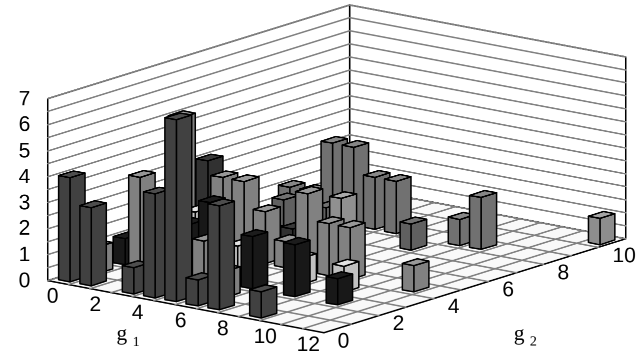
6.06 versus 3.74 ($z = 3.308$). What appears to be happening is that the first players in both games try early on to use their power to commit to free riding, but only in the best-shot game do the second players allow them to do so.

This difference is illustrated in Table IV. Here we indicate the "punishments" by second players conditional on the choice of the first players. Define a punishment as a choice of $g_2 = 0$ in response to a $g_1 = 0$. Table IV shows that the probability that a $g_1 = 0$ will be punished is about three times higher in the sequential game than in the best-shot game. A similar result follows if we define punishment more broadly to be a $g_2 \in [0, 2]$ in response to a $g_1 \in [0, 2]$. Hence, there is a significant difference in how players reply to the subgame perfect move by a first player—in the sequential game they are far more likely to punish it.

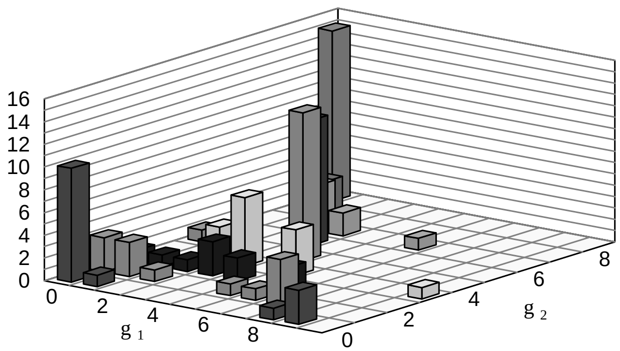
Finally, it is worth noting that in the sequential game there is little evidence that second movers reward generous first movers. For instance, 24 of the 294 first moves were $g_1 \geqslant 8$. The average reply by second players is 1.5, and the median reply is 0. Hence, almost no one saw a need to reward or equalize payoffs by giving above the best reply.

4.3. *Summary*

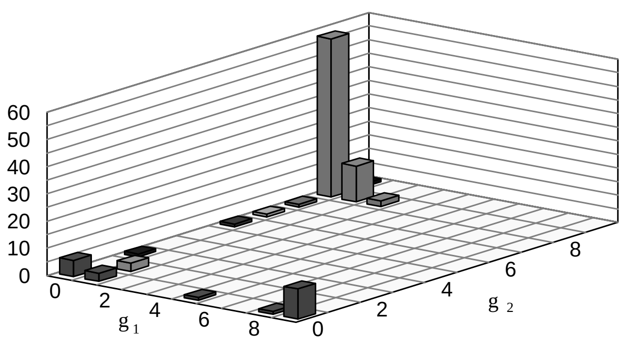
The main results can be summarized in Fig. 3. Here we illustrate the frequency of outcomes over the last five rounds of play. We can easily see, as we move from the simultaneous to the sequential to the best-shot, that the data become more and more organized. Figure 3a shows that play in the simultaneous game is fairly symmetric across the two players, and total provision often falls above the equilibrium prediction of 9. Turning to the sequential game (Fig. 3b), the data begin to fall along two axes. The first



(a) Simultaneous



(b) Sequential



(c) Best-shot

FIG. 3. Frequency of outcomes in the last five rounds.

and most significant axis is along the diagonal where $g_1 + g_2 = 8$, that is, where the second player chooses his best reply, bringing the total public goods up to 8. However, there is a significant group of punishers. These form the second axis along the opposite diagonal where $g_1 \approx g_2$. Note that while punishment is significant, few of the choices put the total above 8, that is, there is little rewarding.[12] Finally, Fig. 3c shows the best-shot game. Clearly there is only one point of any significance here, and that is the subgame perfect equilibrium.[13]

5. IMPLICATIONS FOR THEORY

This study of three different, yet similar, public goods games has provided some valuable insight into when we should expect the selfish equilibrium prediction to be a good approximation for actual behavior. In all three games the prediction is that only one person contributes to the public good, and that the resulting payoff distribution strongly favors the free rider. Our results reveal that this prediction fails in the two summation games. Subjects behave very similarly in the sequential and simultaneous games despite the equilibrium prediction that the behavior in one should be just the opposite of the other. Hence there is no support for the prediction provided by Varian (1994), and it is clear that the ability to commit to ride free does not limit equilibrium deviations. While it is tempting to argue that the unequal payoff distribution is what causes the prediction to fail, our results show that not all such equilibria are prone to deviations. Although the predicted distribution of payoff is identical in the best-shot and sequential games, we find that the subgame perfect outcome is reached in the best-shot game.

How can we determine whether actual play of a game will be consistent with the selfish prediction? Prasnikar and Roth (1992) propose that we determine whether the incentives off the equilibrium discourage deviations. While this explanation sheds light on the difference found between the best shot and ultimatum games, it does not *a priori* help explain the difference we observe between the best shot and sequential games. In both of these games, player two's incentive to play his equilibrium strategy decreases as player one increases her contribution. Thus the equilibrium should be

[12] In contrast, Croson (1998) finds evidence of positively correlated contributions in linear simultaneous-move public goods games.

[13] One may ask whether the differing complexities of the games affected the results. To examine this we administered a test question at the very end of the experiment. Subjects were told to make choices for both Red and Blue players and to calculate payoffs for each. We then flipped a coin to determine the role for which subjects would be paid. Of the 42 subjects in each game, three or four subjects per game made errors in calculating payoffs in the bonus round. Thus, subject errors are not likely to explain the results.

enforced in both games. Could our results be due to a difference in the strength of this enforcement? Unfortunately it is not possible to determine whether the incentive to deviate is stronger in one game than in the other. While a small increase in the initial contribution has no effect on player two's response in the best-shot game, it causes an immediate reaction in the sequential game. Thus, one might argue that locally there is a larger incentive for equilibrium play in the sequential game.

However, if we examine the actual play and thus the incentives that arise in the game, then the incentive hypothesis does suggest a difference. In the sequential game the second movers are far more willing to punish selfishness, and hence a player one can on average increase her payoff by deviating from the equilibrium. This is not true for the best-shot game. Here if player one deviates from the equilibrium she will on average reduce her earnings. Unfortunately viewing the incentive hypothesis from this ex post perspective does not help us determine when the selfish equilibrium prediction is likely to be a good approximation. It does, however, suggest that player two's behavior is key to understanding when the selfish prediction is appropriate.

Similar to other experimental evidence, player two's behavior reveals that he has a preference both for his private payoff and for that of player one. This leads us to ask whether recent models of social preferences can help us understand the differences in play. One class of these models suggests that subjects derive utility both from their private payoff and from an equal distribution of payoffs.[14] Thus, these "difference-aversion" models predict that equilibria with unequal payoff distributions are less likely to be good approximations of actual play. However, with preferences increasing in private payoff they also predict that we should observe more equilibrium play in the best-shot game. The reason for this is that although there are outcomes that result in an equal distribution of payoffs, these also entail a low private payoff for both contributors. Hence subjects who have a preference for both equality and private payoff will be more likely to choose the equilibrium outcome in the best-shot game.

The insight gained from difference aversion is that the equilibrium prediction is more likely to fail when the equilibrium payoffs are unequal and there are equal payoff possibilities that provide the disadvantaged party with an increase in private payoff. What matters is not only the opportunity to play fairly but also the selfish motivation for doing so.

Unfortunately difference aversion fails in predicting what appears to be one of the driving forces for the difference between the best shot and sequential game: the change in player two's response to an initial

[14] Loewenstein *et al.* (1989), Bolton (1991), Fehr and Schmidt (1999), and Bolton and Ockenfels (2000).

contribution of zero. As shown in Table IV, second movers generally prefer payoffs $\pi_2 = 0.35$ and $\pi_1 = 1.14$ to $\pi_2 = \pi_1 = 0$ in the best-shot game, whereas the opposite often holds in the sequential game. Since the models of difference aversion are based solely on outcome, they cannot explain this difference in response.

The only difference in the best-shot and sequential games is in payoffs off the equilibrium, hence if a model of fairness is to capture this change of preferences then the outcomes not chosen must somehow enter the evaluation of the outcome chosen. One class of models that does allow for this possibility is the models of reciprocity. The argument in these models is that subjects want to reciprocate kind actions with kindness and unkind actions with unkindness. What is defined as an intentionally kind action depends on the alternatives that could have been chosen.[15] Rabin (1993) and Dufwenberg and Kirchsteiger (2000) propose that the threshold for what is kind is a function of the largest and smallest Pareto efficient outcomes that could have been chosen. Falk and Fischbacher (2000) argue instead that the reference point that defines a kind act is an equal distribution, but that the intention behind an action depends on the options not chosen.[16] Levine (1998) proposes a model where kindness toward others depends on others' attitudes, which are inferred via actions. Changes in the payoff opportunities may influence the ability to make such inferences and thus affect one's evaluation of the altruistic attitudes of an opponent. With the evaluation of an action being a function of the action not chosen, these models have a larger potential for predicting the change in preferences that we observe in the two sequential games.

While all of the current fairness models provide valuable insight into the deviations from equilibrium, they all fail in one respect. In predicting behavior for the sequential game both classes of fairness models predict that second movers, who are sufficiently concerned with fairness, increase contributions in response to a large initial contribution. As shown in Fig. 3, our experimental results do not support this increase in contributions.[17]

[15] Bolton *et al.* (2000) suggest that by incorporating an endogenous reference point in the difference aversion models, these models may also explain the different response from the second player. As stated above, we agree that what is needed to capture the difference between these games is that the payoff at paths not chosen affects the evaluation of that chosen.

[16] Since the intention of choosing the unequal payoff distribution is somewhat reduced in the best-shot game, we should see an increase in the number of second movers who prefer their best response.

[17] This finding is consistent with that of Charness and Rabin (2000), who find that there is little evidence of sacrifice to reciprocate good behavior.

In sum, our results suggest that the selfish equilibrium prediction is fragile when the equilibrium payoffs are unequal and there are alternative outcomes that increase both equality and the payoff to the disadvantaged party. Furthermore, if models of fairness are to predict the observed difference across the three games then they must allow the evaluation of action to depend on the actions *not* chosen.

6. CONCLUSION

With the mounting evidence on the importance of altruism and fairness in economic laboratory experiments, there has been a move to develop predictive models of this behavior. Developing such models requires a careful, deliberate, and systematic approach to the data. It is important to identify, in controlled settings, the personal and environmental factors that are most important to subjects in evaluating fairness.

We try to highlight several aspects of fairness by considering three very similar games with identical payoff tables and nearly identical equilibrium predictions. The difference between the sequential and simultaneous games is simply the order of play. This difference reveals that, while the pull of equilibrium is evident in early rounds—with the first movers attempting to exploit their advantaged position—the pull of fairness eventually dominates—simultaneous and sequential play are very similar by the end of the experiment. Moreover, while low contributions by first movers are often punished, high contributions are seldom rewarded.

The difference between the sequential and best-shot games is solely in the off-the-equilibrium-path payoffs. We find that, even though the subgame perfect equilibria are the same, only in the best-shot game is this observed. In particular, selfish acts are tolerated in the best-shot game but are punished in the sequential game. It thus appears that when payoffs off the equilibrium path make it more difficult to be fair, a selfish act by the first mover is seen as more tolerable. However, when the first mover has the option to be fair, then a selfish move is seen as more egregious by second movers. As a result, not only is the actual allocation producing fairness, but the road to that allocation and the roads not taken along the way are also inputs into the production of fairness.

What does our work portend for future research on fairness? Fairness, it seems, is a complex and dynamic concept with many varied inputs. The rules, the payoff possibilities, the intentions, and the context of the game are all potential inputs into the production of fairness. With deliberate and carefully designed studies in the future, subjects can reveal to us what makes an allocation more or less fair and can help us build a better predictive model of behavior in situations with unequal equilibrium payoffs.

APPENDIX: SUBJECTS' INSTRUCTIONS FOR THE SEQUENTIAL PUBLIC GOODS GAME

The University of Wisconsin,
Department of Economics

WELCOME

This experiment is a study of group and individual investment behaviors. The instructions are simple. If you follow them carefully and make good investment decisions you may earn a considerable amount of money.

The money you earn will be paid to you, in cash, at the end of the experiment. A research foundation has provided the funds for this study.

HOW YOU MAKE MONEY

First, you will get $3.00 put into your earnings account just for being willing to participate. The money you make from your investment decisions will be added to this account as the experiment proceeds.

Your identity will be kept private throughout the experiment. Neither the people running the experiment nor the other participants will ever know your name, nor will they be able to link you with any of the decisions made in the experiment.

Your decisions will be recorded by the computer. At the end of the experiment you will receive your cash payment in a sealed envelope so that no one but you knows how much you have earned.

Please do not talk to any other participant during the experiment.

THE TWO INVESTORS

In this experiment you will make a series of 14 investment decisions. For each investment decision you will be randomly paired with *one* other participant. Your investment returns will depend on the investment decisions that you and the other participant make.

IMPORTANT NOTICE: For each investment decision you will be *randomly* paired with a *different* participant. You will never play against the same participant two times in a row.

In each investment decision, one participant will be known as the BLUE Investor, and one participant will be known as the RED Investor. We will tell you at the start of the experiment whether you will be a BLUE investor or a RED investor. Your color will be the same throughout the experiment.

YOUR INVESTMENT DECISION

Each of the two investors can purchase Investment Units. Investment units cost 10 cents per unit. For instance, if you purchase 6 units, we will subtract $0.60 from your investment earnings. Each participant can purchase anywhere from 0 to 20 units.

What you earn from the investment will depend on the number of units purchased by you and the other participant. The two investors, however, will not earn the same amount of cash from the investment. Your earnings will depend on whether you are the BLUE investor or the RED investor.

The table on the following page can help you calculate the earnings from the investment. As you can see in the table, earnings depend on the TOTAL number of investment units purchased by both participants.

MAKING THE INVESTMENT CHOICES

For every investment decision, the RED investors will always make their investment decisions first. When all RED participants have entered their decisions into the computer, the computer will randomly match each RED participant with a BLUE participant. The choice of the RED investor will then be revealed to the BLUE investor. The BLUE investors will then be asked to make their investment choices, each knowing the number of investment units already purchased by the RED investor in their pair. When all the BLUE participants have entered their decisions, the computer will calculate the returns for both investors.

[The Table shown in Fig. 1 appears on the following page of the Instructions.]

CALCULATING YOUR EARNINGS FOR EACH INVESTMENT CHOICE

The best way to explain how to use the table to calculate your earnings is with some examples.

Example 1. Suppose both investors purchased zero investment units. Then both investors would get a return of $0 and spend nothing on investment units, hence earning nothing for this investment decision. If either investor had purchased one unit, at a cost of $0.10, RED's return from the total investment would go up by $0.15, and BLUE's would go up by $0.16.

EXAMPLE 2. Suppose the RED investor chooses to purchase 5 investment units, and the BLUE investor purchases 2 units. Then the total units purchased is $5 + 2 = 7$. Turning to the row labeled 7 in the table, we see that the RED investor will earn \$1.03 from the investment and the BLUE investor will earn \$1.04 from the investment. However, the RED investor must pay $5 \times \$0.10 = \$0.50$ for his 5 investment units, yielding net earnings of $\$1.03 - 0.50 = \$0.53$. Likewise, the BLUE investor must pay $2 \times \$0.10 = \$0.20$ for his 2 investment units, yielding net earnings of $\$1.04 - 0.20 = \$0.84$. Notice, we can also use the table to see how investors can change their earnings. If either investor had purchased one more unit, at a cost of \$0.10, RED's return from the total investment would go up by \$0.13, and BLUE's would go up by \$0.11.

INFORMATION TO YOU

After all participants have made their decisions, the computer will inform you of the outcome of your investment. You will be told the investment decisions, the investment returns, and the net earnings after paying for investment units of both investors. No one will be told of the investments or earnings of other participants in the experiments.

YOUR CASH EARNINGS

Your investment earnings will be tallied by the computer. At the end of the experiment your earnings from investments will be added to the \$3 starting payment to determine your total cash earnings. This will be paid to you in a sealed pay envelope at the end of the experiment. Neither the people running the experiment nor the other participants will ever be able to tie you to any of your investment decisions or to your investment earnings.

Your decisions and earnings are strictly private information.

SUMMARY

The important things to remember are:

1. Investment Units cost \$0.10 each, which will be subtracted from your Investment Return.

2. Investment Returns depend on the total amount invested by both Red and Blue investors.

3. The Red investor moves first. After learning what the Red investor chose, the Blue investor moves second.

4. For each round you will be randomly matched with a new partner.

5. There are 14 rounds in total.

6. Your earnings and choices are all secret, private information.

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